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Code Description for Generation of Meteorological Height and Pressure Level and Layer Profiles

by J L Cogan

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14. ABSTRACT
This report documents the computer source code used in the US Army Research Laboratory's (ARL) analysis of meteorological soundings. It complements previous ARL technical reports that describe the algorithms and provide input and output samples. The software produces profiles of meteorological variables for levels and layers as defined by user input height or pressure levels. It can process input profiles from sensing systems such as radiosonde, lidar, or wind profiling radar, and from profiles derived from numerical weather model output such as from the Weather Research and Forecasting model. Some changes to the input routine may be required for different input types and formats.

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1. Introduction

This short document presents the code for the generation of user-defined profiles of meteorological variables. The input profiles or soundings can come from a variety of sources, for example, from Weather Research and Forecasting (WRF) or other model output and World Meteorological Organization (WMO) or other radiosonde soundings. There are 2 main versions or "methods" that produce output in height- or pressure-based profiles of interpolated level and integrated mean layer values. For most forms of input, only the input routine has to be modified, leaving the rest of the program unchanged. However, certain forms of input may require modest changes to one or more other routines. To date, that has been required only once, for use with rawinsonde observation (RAOB) data archived by the National Oceanic and Atmospheric Administration (NOAA). More information on the programs may be found in previous reports.[1,2]

The several routines are shown here for each of the versions including the one for NOAA-archived RAOBs. A list of the routines required for each version is presented. The `flagsound` routine or function initializes the relevant arrays with the missing data value flag of `-999`. The `checkdata` function can be inserted in the program to check several input, intermediate, or soon-to-be output values before the output is written. The `clean_data` function provides a gross error check. In addition, a short users' guide describes how to use the programs once compiled. The other functions are described in the aforementioned references. Most of the routines require the use of the include file `convert.h` and that, in turn, uses the include file `metstruct.h`. Since the code is in standard American Standard Code for Information Interchange (ASCII) "C", it should compile and run on any system supporting that language. To date it has run on various Windows® and Linux® computers.

These source code files are released subject to the ARL Open Source License. A copy of the license is in the Appendix, and a short summary of the license is included in each source code file.

1.1 Extracting the Source Code Files

The source code for each of the routines (called functions in C) are included here. Files common to more than one version are repeated with each version they are used with. The include files `convert.h` and `metstruct.h` are used by nearly all the routines.

This document contains links to the embedded, or "attached", copies of the data files used in preparation of this report. The data files can each be extracted when viewing the electronic version of this document by "right clicking" on one of the icons and selecting the "`Save Embedded File to Disk...`" menu option.

2. Routines by Version

2.1 Common Include Files

These are the include files used by most of the routines:

`convert.h`

`metstruct.h`

2.2 Height-Based Output using University of Wyoming RAOBs

The following list contains the files for height-based output using RAOB input from the University of Wyoming website. The executable name is `convertwyo`. Many of the files appear in other versions without modification.

`convertdatawyo.c`

`msgvalues.c`

`flagsound.c`

`level.c`

`layer.c`

clean_data.c

tvfromtemp.c

prscomp.c

readwyo.c

writeusrmsg.c

writeusrlvls.c

checkdata.c

2.3 Pressure-Based Output using University of Wyoming RAOBs

The following list contains the files for pressure-based output using RAOB input from the University of Wyoming website. The executable name is `convertprswyo`. Many of the files appear in other versions without modification.

convertdataprswyo.c

msgvaluesprs.c

flagsound.c

levelprs.c

layerprs.c

clean_data.c

tvfromtemp.c

readwyo.c

writeusrmsgp.c

- writeusrlvlsp.c
- checkdata.c

2.4 Height-Based Output using WRF

The following list contains the files for height-based output using profiles generated from WRF output. The executable name is `convertwrf`. Many of the files appear in other versions without modification.

- convertdatawrf.c
- msgvalues.c
- flagsound.c
- level.c
- layer.c
- clean_data.c
- tvfromtemp.c
- prscomp.c
- readwrf.c
- writeusrmsg_wrf.c
- writeusrlvls_wrf.c
- checkdata.c

2.5 Pressure-Based Output using WRF

The following list contains the files for pressure-based output using profiles generated from WRF output. The executable name is `convertprswrf`. Many of the files appear in other versions without modification

- `convertdataprswrf.c`
- `msgvaluesprs.c`
- `flagsound.c`
- `levelprs.c`
- `layerprs.c`
- `clean_data.c`
- `tvfromtemp.c`
- `readwrf.c`
- `writeusrmsgp_wrf.c`
- `writeusrlvlsp_wrf.c`
- `checkdata.c`

2.6 Height-Based Output using NOAA RAOBs

The following list contains the files for height-based output using RAOB input from the NOAA archive website. The executable name is `convertnoaa`. Many of the files appear in other versions without modification.

- `convertdatawyo.c`
- `msgvaluesnoaa.c`

- flagsound.c
- level.c
- layer.c
- clean_datanoaa.c
- tvfromtemptd.c
- prscomp.c
- readnoaa.c
- writeusrmsg.c
- writeusrlvls.c
- checkdatanoaa.c

2.7 Pressure-Based Output using NOAA RAOB

The following list contains the files for pressure-based output using RAOB input from the NOAA archive website. The executable name is convertprsnoaa. Many of the files appear in other versions without modification.

- convertdataprswyo.c
- msgvaluesprsnoaa.c
- flagsound.c
- levelprs.c
- layerprs.c
- clean_datanoaa.c

tvfromtemptd.c

readnoaa.c

writeusrmsgp.c

writeusrlvlsp.c

checkdatanoaa.c

3. Brief Users' Guide

This brief user's guide presents the steps to run the programs for generation of height- and pressure-based soundings of level and layer values of meteorological variables. The procedures to run the program are not complex, and past experience suggests that users should be able to run the program easily. Additional information may be found in previous US Army Research Laboratory (ARL) reports[1,2] including input and output samples.

3.1 Rawinsonde Observation Input

The input routine in the current version of the program is designed for RAOBs of the type found at the University of Wyoming web site `http://www.weather.uwyo.edu/`. For RAOBs with a different format than the University of Wyoming, normally only the source code for the input routine must be revised, but no other changes to the program are needed. An exception involves data from the NOAA archive site `http://www.esrl.noaa.gov/raobs/`. The data are read in nearly the same way, but the split between wind and temperature/humidity (TH) special levels leads to some changes to one other routine. If changes are made, the whole program is then recompiled.

The RAOB input routine for University of Wyoming formatted data has code that can handle certain types of missing data at the beginning and the end of the data section:

1. Stations at heights above the 1,000-hPa level often report the standard levels along with computed heights. Since there are no data below the surface, the

rest of the fields on those lines are blank. The program will run if there are one or more contiguous lines with missing data at the beginning of the data section.

2. At the top of the sounding, sometimes the moisture, the thermal, both thermal and moisture, and/or the wind data are missing. Missing data items in the input are filled with blanks (no missing data indicator). The program will run if one or more contiguous lines with missing thermal or wind data are at the end of the data section. However, it will not handle all possible situations. For many unusual situations the program ends after printing an error message telling the user to check the input.

If the program encounters a wind speed greater than 221 kn before the end of useful wind data, it will end the input at the height immediately below and produce output as if the data ended at the line below the 221-kn speed. To date, this situation has only occurred when the wind fields were missing and other quantities, such as potential temperature that almost always has a value greater than 221 were encountered in the data line.

The RAOB input from the NOAA archive contain the standard levels (e.g., 1,000, 925, and 850 hPa) plus the special levels for wind and for TH. Missing data items are indicated by 99999 where, for example, a special level for TH will omit wind speed and direction and vice versa. Since all fields are filled, the data are read as one set of data lines, including the special levels. The levels with TH and wind data are processed separately in either the `msgvaluesnoaa` or the `msgvaluesprsnoaa` routines as appropriate.

3.2 WRF Input

The current input routine reads in "soundings" generated from WRF using a Linux script developed by Reen[3] that employs National Center for Atmospheric Research (NCAR) command language (NCL) programs that are available with the WRF software package. To date, all data lines have contained the appropriate values and consequently no special processing is needed as with the RAOB data. If other sources of model data are used, but the data fields and format of the model-generated sounding are the same, then no change is required to the input routine. If the model-derived sounding has a different format or, for example, a different order to the variables in

the data lines, then the input routine would require some modification. In that case, the whole program is recompiled.

The user defines the structure of the output by listing a column of heights or pressures in a text file that ends with `_lvls` (e.g., `usrprs_lvls`). The input levels define the output levels and the boundaries for the layers. Since the height output normally is above ground level (AGL), the first height usually is 0. Height or pressure must monotonically increase or decrease, respectively (i.e., no repeated values and no following increase of pressure or decrease of height).

3.3 Procedure to Run the Height-Based Program

The following are the procedures for running the height-based program:

1. Check the input sounding for normal format. For the RAOB data from the University of Wyoming, if there are spaces instead of data items in the interior of the data section (i.e., not at the beginning or the end), the program may or may not run, but if it does the output sounding(s) will be incorrect. For the WRF-derived soundings or the RAOB soundings from the NOAA archive, check to see if all fields are filled. As noted earlier, missing data in the NOAA format are indicated by 99999, but should not contain blank fields in the data lines. For both RAOB and WRF, check the header for the correct number of fields. A University of Wyoming RAOB must have the words `Observations at` before the date time group. To date, that has always occurred, but exceptions could happen. Note that the use of the `./` before the executable name may not be needed for some operating systems (see Section 3.5.3).

2. Check that the correct `lvls` files for the appropriate output soundings are in the same directory as the executable. The current version uses the file `usrhgt_lvls`.

3. Check the `input_parameters` file for the correct paths for input and output. This file should be in the same directory as the executable.

4. Do the following depending on the input:

   (a) For RAOBs from the University of Wyoming, type and return the command line `./convertwyo␣InputFileName ↵`.

(e.g., `./convertwyo␣RAOB_ABC_20140520` ↵).

(b) For RAOBs from the NOAA archive, type and return the command line
`./convertnoaa InputFileName` ↵.
(e.g., `./convertnoaa␣RAOB_XYZ_20140520` ↵).

(c) For WRF-generated soundings in the format produced by the extraction script,[3] type and return the command line
`./convertwrf␣InputFileName` ↵,
(e.g., `./convertwrf␣WRF_ABC_20140520` ↵).

3.4 Procedure to Run the Pressure-Based Program

The following are the procedures for running the pressure-based program:

1. Check the input sounding for normal format as in Section3.3 for the height-based program.

2. Check that the correct `lvls` files for the appropriate output soundings are in the same directory as the executable. The current version uses the file `usrprs_lvls`.

3. Check the `input_parameters` file for the correct paths for input and output. This file should be in the same directory as the executable.

4. Do the following depending on the input:

   (a) For RAOBs from the University of Wyoming, type and return the command line `./converprstwyo␣InputFileName` ↵,
   (e.g., `./converprstwyo␣RAOB_ABC_20140520` ↵).

   (b) For RAOBs from the NOAA archive, type and return the command line
   `./convertprsnoaa␣InputFileName` ↵.
   (e.g., `./convertprsnoaa␣RAOB_XYZ_20140520` ↵).

   (c) For WRF-generated soundings in the format produced by the extraction script,[3] type and return the command line
   `./convertprswrf␣InputFileName` ↵,
   (e.g., `./convertprswrf␣WRF_ABC_20140520` ↵).

3.5 Notes

3.5.1 `lvls` Files

The files ending in `_lvls` provide the level and layer structure information for the program. If $1, ..., n-1$ `lvls` files out of n such files are not in the same directory, then the program skips that (those) part (parts) of the calculations, and if no `lvls` files exist at all, then the program quits without crashing after printing an error message.

3.5.2 `input_parameters` Files

The `input_parameters` file is required. It contains the input and output directories. Though they may be the same or different, a line for each is needed. Without that file, the program quits after printing an error message. If there is only one line, the program runs without producing output.

3.5.3 A Note for Windows Systems

To run in a Windows command prompt window, type the executable name without the preceding `./` followed by the input filename (e.g., `convertwyo␣RAOB_ABC_20140520` ↵).

4. Conclusion

This report presents the source code used in the analysis of vertical profiles of meteorological variables. The programs may be used to interpolate vertical profiles at user-defined height or pressure levels and compute integrated mean values for layers defined by the aforementioned height or pressure levels. The input may come from observation systems such as radiosondes, lidars, and radar wind profilers as well as from profiles generated from numerical weather model output such as from the WRF model.

These programs have evolved over time to account for new types of input as well as upgrades to, for example, produce additional types of output profiles. It is expected that this process will continue, including upgrades suggested by users of the software. The data files used for the report are embedded in the electronic version and may be extracted using the links in Section 2.

5. References

1. Cogan J. A generalized method for vertical profiles of mean layer values of meteorological variables. Adelphi Laboratory Center (MD): Army Research Laboratory (US); 2015 Sep. Report No.: ARL-TR-7434. http://www.arl.army.mil/www/default.cfm?page=239.

2. Cogan J. A method for evaluation of model generated vertical profiles of mean layer values of meteorological variables. Adelphi Laboratory Center (MD): Army Research Laboratory (US); 2016 Mar. Report No.: ARL-TR-7608. http://www.arl.army.mil/www/default.cfm?page=239.

3. Reen B. Army Research Laboratory (US), Adelphi, MD. Personal communication, 2015.

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List of Symbols, Abbreviations, and Acronyms

Symbols

TH temperature/humidity

Acronyms

AGL above ground level

ARL US Army Research Laboratory

ASCII American Standard Code for Information Interchange

NCAR National Center for Atmospheric Research

NCL NCAR command language

NOAA National Oceanic and Atmospheric Administration

RAOB rawinsonde observation

WMO World Meteorological Organization

WRF Weather Research and Forecasting

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